412TW-PA-17485

Telemetry System Data Latency.

Jon Morgan

AIR FORCE TEST CENTER
EDWARDS AFB, CA

13 July 2017

4
1
2
T
W

Approved for public release; distribution is unlimited.
412TW-PA-17485

412TH TEST WING
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
13-07-2017	Technical Report	1-04-2017 – 13-07-2017

4. TITLE AND SUBTITLE

Telemetry System Data Latency

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Jon Morgan

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)

JT3
215 East Yeager BLVD
Edwards, AFB
93524-6834

8. PERFORMING ORGANIZATION REPORT NUMBER

412TW-PA-17485

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

412Th Test Wing
Edwards, AFB
93524-6843

10. SPONSOR/MONITOR'S ACRONYM(S)

N/A

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release A: distribution is unlimited.

13. SUPPLEMENTARY NOTES

CA: Air Force Test Center Edwards AFB CA CC: 012100

14. ABSTRACT

This paper documents measured telemetry data latencies for various test configurations at Edwards Air Force Base (AFB).

15. SUBJECT TERMS

Telemetry Data Latency

16. SECURITY CLASSIFICATION OF: Unclassified			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					412 TENG/EN (Tech Pubs)
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified	None	33	661-277-8615

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Table of Contents

1. INTRODUCTION 3
2. PURPOSE 6
3. TEST CONFIGURATION 6
4. DXDECOM 8
5. ION BUS 10
6. BASELINE MCS 11
7. MCS WITH DXDECOM CAPTURE AND SOFTWARE DECOM 13
8. MCS WITH IOPLEX CAPTURE AND SOFTWARE DECOM 15
9. MCS WITH GSSRS IRIG 106 CHAPTER 10 CAPTURE AND SOFTWARE DECOM 17
10. MCS WITH IOPLEX CAPTURE AND SOFTWARE DECOM AND WITHOUT ION BUS 20
11. MCS COMPARISON 22
12. DATA ACQUISITION AND TRANSMISSION SYSTEM 24
13. IADS SYSTEM LATENCY 27
14. RF CODING LATENCY 29
15. TOTAL SYSTEM LATENCY 30
16. REVISION HISTORY 31
17. METADATA 31

List of Figures

Figure 1-1 Typical Flight Test Configuration 3
Figure 1-2 Mission Control System (MCS) / Interactive Analysis and Display System (IADS) Overview 4
Figure 3-1 Composite Output 6
Figure 3-2 10-bit Word Time vs Data Rate 7
Figure 4-1 DxDecom Data Flow 8
Figure 5-1 ION Bus Data Flow 11
Figure 6-1 MCS Data Flow 12
Figure 7-1 MCS with DxDecom Capture and Software Decom Data Flow 13
Figure 8-1 MCS with IOPlex Capture and Software Decom Data Flow 16
Figure 9-1 MCS With GSSrs Capture and Software Decom Data Flow 18
Figure 10-1 All Software MCS with IOPlex Capture and Software Decom Data Flow 21
Figure 12-1 DATS Data Flow 25
Figure 13-1 IADS Data Flow 28

List of Tables

Table 1-1 Test Configurations Overview 5
Table 3-1 Bit/Word Times 6
Table 3-2 Data Pulse in Words 7
Table 4-2 Test Results (DxDecom Observations) 10
Table 5-1 Test Results (ION Bus Measured Latency) 11
Table 6-1 Test Results (MCS Measured Latency) 12
Table 7-1 Test Results (MCS with Software Decom Measured Latency) 14
Table 7-2 Software Decom Latency to DxDecom Latency Comparison 15
Table 8-1 Test Results (IOPlex Capture Measured Latency) 16
Table 8-2 Software Decom / IOPlex Latency to Software Decom / DxDecom Latency Comparison 17
Table 9-1 Test Results (Network Bursts) 18
Table 9-2 Test Results (Auto Sized Buffers) 19
Table 9-3 Test Results (WIN AUTO, LMF1G, and LMG1G-10ms results) 20
Table 10-1 Test Results (All Software MCS Measured Latency) 22
Table 11-1 MCS Latency Comparison by Scenario with GSSrs 23
Table 11-2 MCS Latency Comparison by Scenario without GSSrs 23
Table 12-1 DATS Test Scenarios 24
Table 12-2 Test Results (DATS Measured Latency Single and Dual Loop) 26
Table 12-3 DATS Single and Dual Loop Latency Comparison 27
Table 13-1 Test Results (Measured Latency) 28
Table 14-1 RF Latencies 29
Table 14-2 RF Latencies in Microseconds 29
Table 15-1 Test Results (Total System Measured Latency) 30

1. INTRODUCTION

This paper documents measured telemetry data latencies for various test configurations at Edwards Air Force Base (AFB). A typical flight test configuration is shown in Figure 1-1 below and the area inside the green border is where various data latencies will be measured.

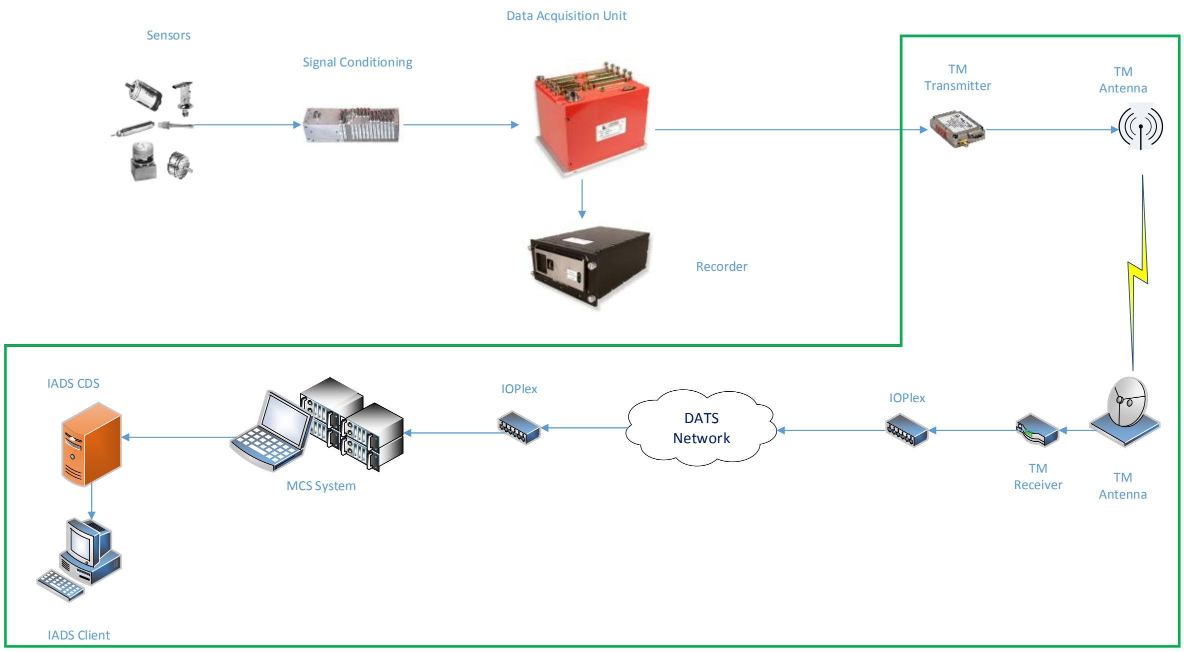


Figure 1-1 Typical Flight Test Configuration

A typical MCS/IADS configuration is shown in Figure 1-2 below.

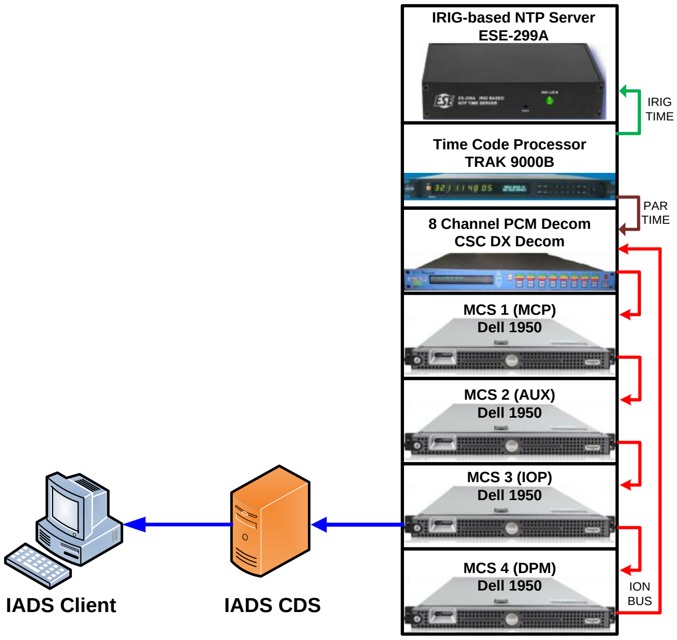


Figure 1-2 Mission Control System (MCS) / Interactive Analysis and Display System (IADS) Overview

Table 1-1 below identifies the various test configurations used for data latency measurements.

Table 1-1 Test Configurations Overview

Test Name	Description
Baseline MCS	• DxDecom processes PCM bit stream • Decom'ed data sent across ION Bus to DPM • DPM processes data and then sends across ION Bus to IOP • Latency is measured at the IOP
MCS with DxDecom Capture and Software Decom	• DxDecom captures PCM bit stream and then sends across ION Bus to AUX • AUX's Software Decom processes PCM bit stream • Decom'ed data sent across ION Bus to DPM • DPM processes data and then sends across ION Bus to IOP • Latency is measured at the IOP
MCS with IOPlex Capture and Software Decom	• IOPlex captures PCM bit stream and then sends via IRIG 218 across Ethernet to AUX • AUX's Software Decom processes PCM bit stream • Decom'ed data sent across ION Bus to DPM • DPM processes data and then sends across ION Bus to IOP • Latency is measured at the IOP
MCS with GSSrs IRIG 106 Chapter 10 Capture and Software Decom	• GSSrs captures PCM bit stream and then sends via Chapter 10 packets across Ethernet to AUX • AUX's Software Decom processes PCM bit stream • Decom'ed data sent across ION Bus to DPM • DPM processes data and then sends across ION Bus to IOP • Latency is measured at the IOP
MCS with IOPlex Capture and Software Decom and without ION Bus	• IOPlex captures PCM bit stream and then sends via IRIG 218 across Ethernet to single MCS node • MCS Node's Software Decom processes PCM bit stream • Decom'ed data sent to MCS Node's DPM • DPM processes data and then sends to MCS Node's IOP • Latency is measured at the IOP
Data Acquisition and Transmission System	Measures telemetry data latency across the Edwards AFB Data Acquisition and Transmission System (DATS) using the baseline MCS for data capture
IADS System Latency	Measures telemetry data latency through the Interactive Analysis and Display System (IADS) using the baseline MCS for data capture
RF Coding Latency	Measures telemetry data latency associated with Space Time Coding (STC) and Low-Density Parity Check (LDPC) encoding.

The data latency was measured using a Mission Control System (MCS), a Pulse Code Modulator (PCM) simulator, a Global Positioning System (GPS) time code unit with a one Pulse Per Second (PPS) output, a signal combiner (built and provided by NASA), and an oscilloscope.

2. PURPOSE

This paper provides data latency information to assist the Modular Mission Control Room Upgrade (MMCRU) project with evaluating various Analysis of Alternatives for the next generation Edwards AFB mission control rooms.

3. TEST CONFIGURATION

The PCM simulator was programmed with a PCM load that defines all words as zero. The simulator's data signal was combined with the GPS's 1 PPS output using the signal combiner to create a composite output as in Figure 3-1 below.

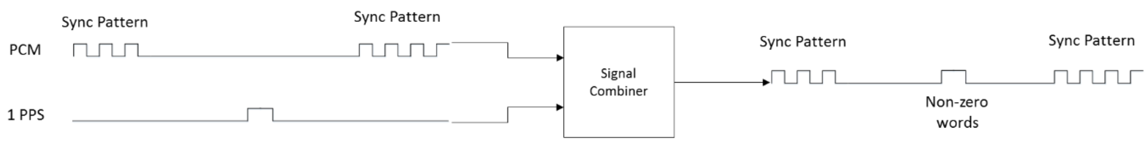


Figure 3-1 Composite Output

This composite output was sent through various distribution paths to the MCS where an application monitored each PCM word looking for non-zero values. When a non-zero value was detected, the application wrote a byte to the computer's serial port. The generated serial port output signal along with the GPS's 1 PPS signal were monitored on the oscilloscope and the time delta between the two signals was measured. The serial port's latency was characterized for these tests and was determined to be between 76 and 114 microsecond (µs). These values are negligible when measuring latencies greater than one millisecond (ms). When measuring latencies less than one ms, a signal from the MCS ION card was used that enabled latency measurements in the nanoseconds.

Unless otherwise stated, all tests were performed with the following bitrates: 128,000 bits per second (bps), 256,000 bps, 512,000 bps, 1,000,000 bps, 5,000,000 bps and 10,000,000 bps. The word size for each test was 10 bits/word. The frame size was 128 10-bit words. The word, frame, and measurement rate transmission characteristics are defined in Table 3-1.

Table 3-1 Bit/Word Times

Data Rate	Single Bit Time	Word Time	Frame Time	Meas. Rate
128Kbps	7.81 µs	78.1 µs	10 ms	12,500
256Kbps	3.9 µs	39.0 µs	5 ms	25,300
512Kbps	1.95 µs	19.5 µs	2.5 ms	50,900
1Mbps	1 µs	10 µs	1.28 ms	99,414
5Mbps	200 ns	2 µs	256 µs	497,070
10Mbps	100 ns	1 µs	128 µs	994,140

The word time versus data rate for 10-bit words is shown in Figure 3-2 below.

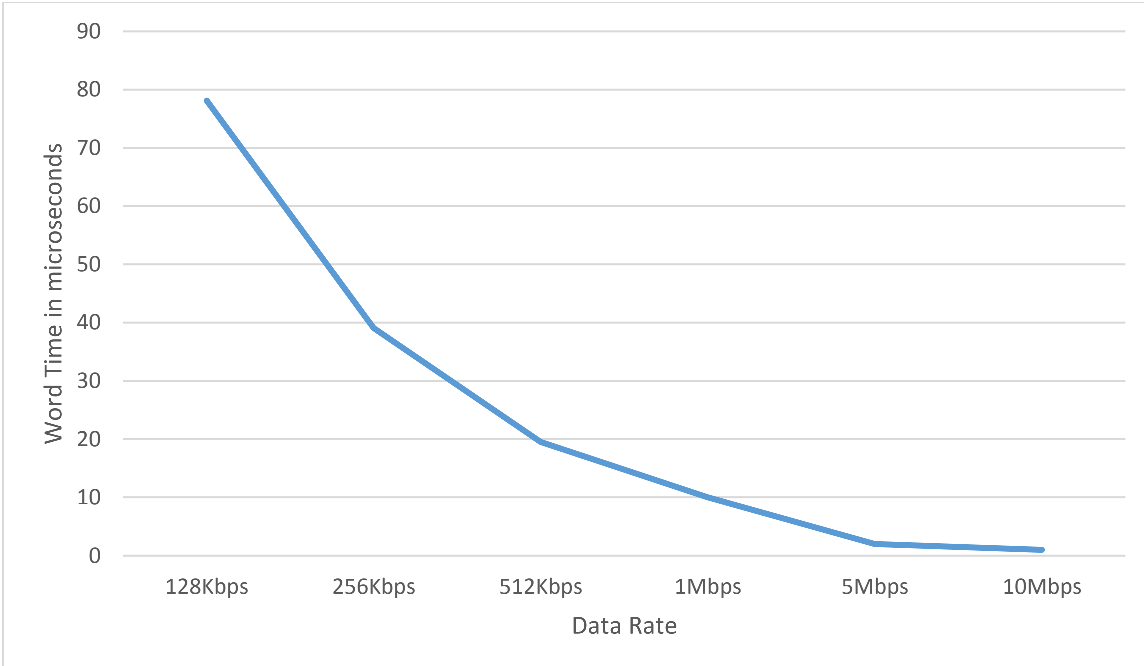


Figure 3-2 10-bit Word Time vs Data Rate

When a data pulse (i.e., a consecutive sequence of ones) arrives at the decom, the sequence of ones may start and stop anywhere within the data word. Consequently, anywhere from one to ten bits may be set in a word; this is shown in Table 3-2 below (bit transmission order is left to right).

Table 3-2 Data Pulse in Words

Row	Word x-1	Word x	Word x+1	Word x+2
1	0000000000	0000000001	1111111111	1000000000
2	0000000000	1111111111	1100000000	0000000000

When the pulse lines up as is shown in Table 3-2 Row 1, the latency is minimal because the decom only has to wait one bit time before the word is ready for further processing. In the case of Table 3-2 Row 2, the decom has to wait 10 complete bit times before the word is ready for further processing. In order to compensate for this disparity, several measurements are observed for both minimum and maximum latency.

Data latency will be affected more by slower data rates than faster data rates, especially when measuring < 200 µs latencies.

When MCS was used to make a measurement, a capture process on an MCS node was run at 10,000 interrupts/sec., which is approximately 100 µs. Any jitter in the range of 0-100 µs can be attributed to this interrupt rate.

An attempt to measure both the minimum and maximum latency was accomplished by continuously triggering the oscilloscope using the GPS 1 PPS signal (one pulse per second) and measuring the latency over an extended period of time (> 1 minute, < 10 minutes). The delta of these measured minimum and maximum latencies may be used to access jitter for the purposes of this paper.

4. DXDECOM

This section documents test results for telemetry data latency through the MCS telemetry processor's hardware decommutator, the DxDecom. The ION bus is the high speed data transfer bus used by the MCS system. More information can be found in the CSRA DxDecom and ION documentation provided with the MCS system.

4.1. Test Scenarios

A single scenario was performed to test the data latency from the PC Simulator through the DxDecom to just before the ION bus. The DxDecom IOC firmware was modified to drive a single pin on the serial port based on the contents of a data tag. The pin was driven high anytime the data word written to the ION bus was non-zero and driven low for any other time. The data flow is shown below in Figure 4-1 .

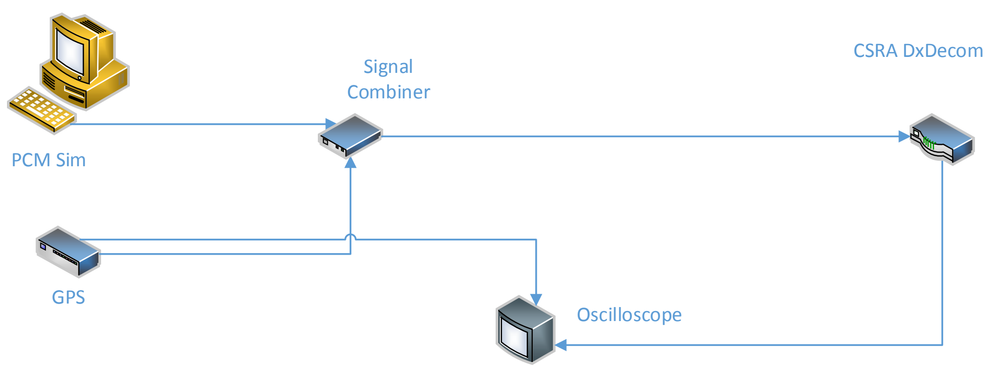
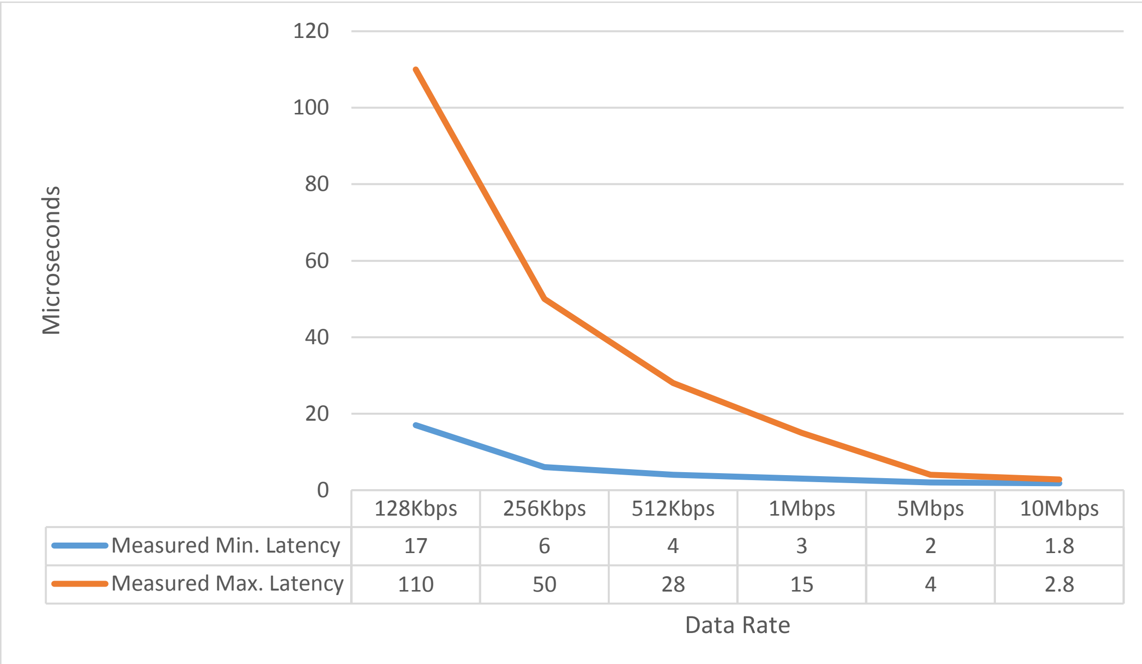


Figure 4-1 DxDecom Data Flow

4.2. Test Results

The measured minimum and maximum latencies are shown in Table 4-1 below.

Table 4-1 Test Results (Dx Decom Measured Latency)



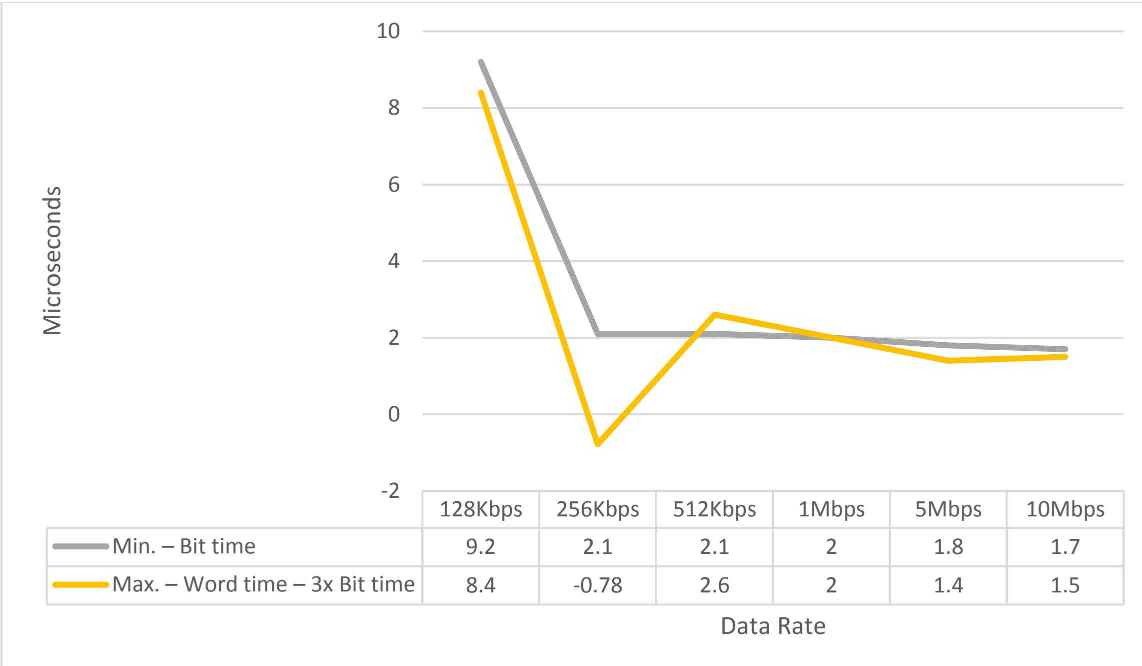
	128Kbps	256Kbps	512Kbps	1Mbps	5Mbps	10Mbps
Measured Min. Latency	17	6	4	3	2	1.8
Measured Max. Latency	110	50	28	15	4	2.8

A single bit time represents the best case scenario (minimum latency) and the word time plus three bit times represents the worst case scenario (maximum latency) of data flow through the DxDecom. The word time plus three bit times is a result of the DxDecom always collecting four input bits before processing. In the best case, the word is one bit long and arrives as the last bit in the four bit processing buffer. The worst case is when the word is ten bits long and the last bit of the word arrives as the first bit of the four-bit processing buffer and the DxDecom must wait for three more bit times before the word can be processed.

4.3. Observations

Two calculated results are shown below in Table 4-2 the minimum latency minus a single bit time (from Table 3-1) and the maximum latency minus a word time (from Table 3-1) minus three bit times.

Table 4-1 Test Results (DxDecom Observations)



	128Kbps	256Kbps	512Kbps	1Mbps	5Mbps	10Mbps
Min. – Bit time	9.2	2.1	2.1	2	1.8	1.7
Max. – Word time – 3x Bit time	8.4	-0.78	2.6	2	1.4	1.5

The test results show jitter in the measurements. The calculated results show if the bit time (from Table 3-1) is subtracted from the minimum measured latency time, the result is approximately 2 µs latency for all data rates with the exception of the 128 kilobits per second (Kbps). If one more bit time is subtracted from the single outlier (128Kbps), the results would also be approximately 2 µs. This implies that total latency through the DxDecom, is greatly affected by the bit time; however, the DxDecom takes approximately 2 µs to process any word. This discrepancy and the discrepancies of the maximum minus word time values can be attributed to simple sampling error, (i.e., not enough samples were taken to ensure complete coverage). This same statement can be made about each of the below results where wide ranges of results occur.

5. ION BUS

This test measures the latency between two ION nodes in the MCS system.

5.1. Test Scenarios

This test used two programs running on two different ION nodes. One program wrote a single byte to the serial port, wrote a single sample to the ION bus, slept for a period of time, and then started over again. The other program listened to the ION bus and when the single sample from the ION bus was received, the program wrote a single byte to the serial port and then went back to listening to the ION bus. Two different interrupt rates were tested. The hardware flow of this is shown in Figure 5-1 below.

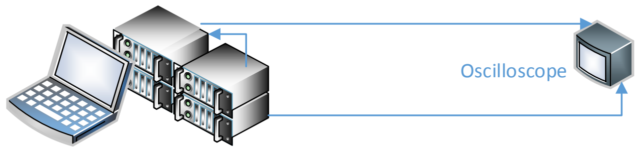


Figure 5-1 ION Bus Data Flow

5.2. Test Results

The results of the two tests are shown in Table 5-1 below.

Table 5-1 Test Results (ION Bus Measured Latency)

Interrupt Rate	Measured Min Latency	Measured Max Latency
10,000/sec	40 µs	145 µs
153,000/sec	40 µs	76 µs

5.3. Observations

The ION bus latency is greatly affected by the interrupt rate.

6. BASELINE MCS

This section documents test results for telemetry data latency through the MCS telemetry processing system.

6.1. Test Scenarios

Three scenarios were tested: Raw data, EU data and APS data.

The Raw data scenario tests the latency of the data path from the PCM simulator through the DxDecom to an MCS node with no EU data processing.

The EU data scenario tests the latency of the data path from the PCM simulator through the DxDecom, converted to EU by the MCS Data Processing Module (DPM) and then passed on to another MCS node. The DPM process runs at a normal rate of 10,000 interrupts/sec (100 µs).

The APS data scenario tests the latency of the data path from the PCM simulator through the DxDecom, through the MCS DPM, through an APS module, and then to an MCS node. The APS module runs at a nominal rate of approximately 10,000 interrupts/sec (100 µs). This APS module simply passes data and performs no special processing.

The MCS data flow is as shown in Figure 6-1 below.

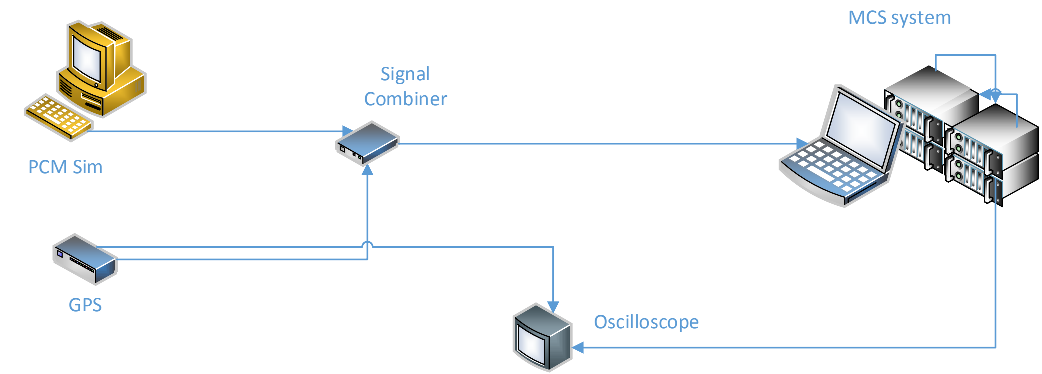


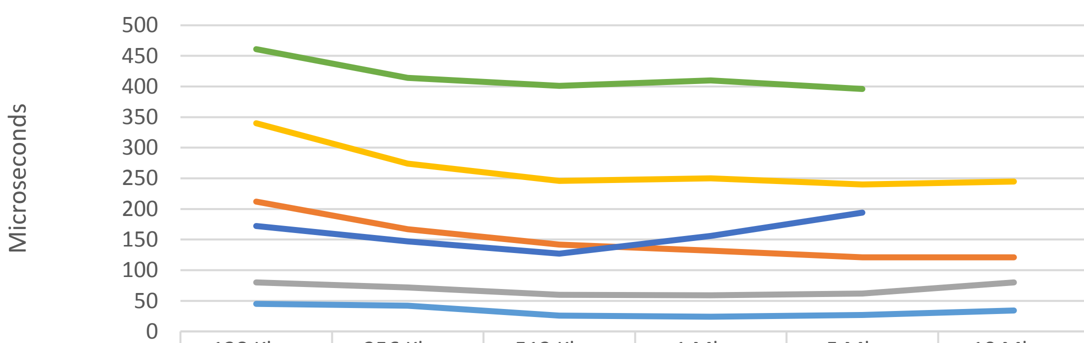
Figure 6-1 MCS Data Flow

In an attempt to determine the minimum latency through MCS, a single case of the Raw data scenario running at 10 Megabits Per Second (Mbps) and 100,000 interrupts/sec (approximately 10 microseconds) was performed.

6.2. Test Results

The three scenarios' results for various data rates are shown in Table 6-1 below. The MCS minimum latency scenario results in a measured minimum latency of 11 µs and a maximum latency of 47 µs.

Table 6-1 Test Results (MCS Measured Latency)



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
RAW Min	45	42	26	24	27	34
RAW Max	212	167	142	132	121	121
EU Min	80	72	60	59	62	80
EU Max	340	274	246	250	240	245
APS Min	172	147	127	156	194	
APS Max	461	414	401	410	396	

Data Rate

6.3. Observations

The test results show all three data scenarios have very low latency, primarily due to the high interrupt rate of the processes that process the data.

7. MCS WITH DXDECOM CAPTURE AND SOFTWARE DECOM

This section documents test results for telemetry data latency through the MCS telemetry processing system using a Software Decom along with the existing MCS ION bus. PCM data will be captured using the existing DxDecom. This scenario matches what MCS currently does for iNet.

7.1. Test Scenarios

A single Raw data scenario tests the latency of the data path from the PCM simulator through the DxDecom's serial data capture, through the Software Decom, and to an MCS node as shown in Figure 7-1 below. No EU processing is performed and the DxDecom is only used to perform serial to parallel conversion and output of this data to the ION bus. No decommutation is performed by the DxDecom. All other latencies should have equivalent deltas to standard MCS processing.

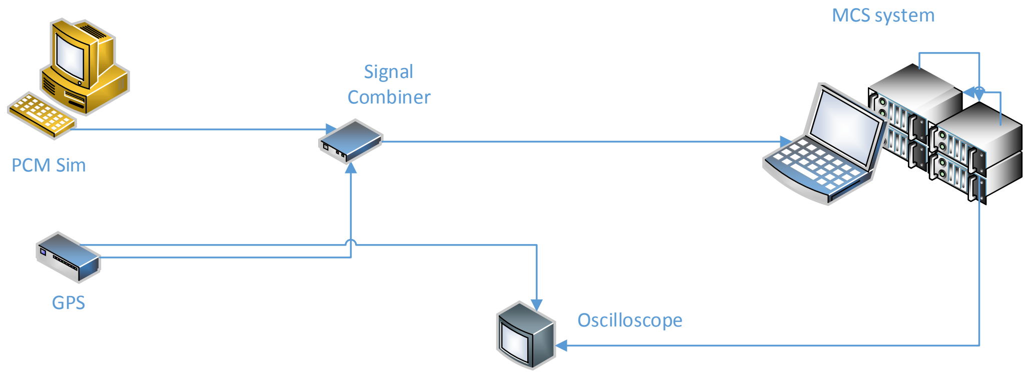


Figure 7-1 MCS with DxDecom Capture and Software Decom Data Flow

7.2. Test Results

The results of the raw data test at various data rates are shown in Table 7-1 below. The DxDecom-based comparable latencies are also included as reference.

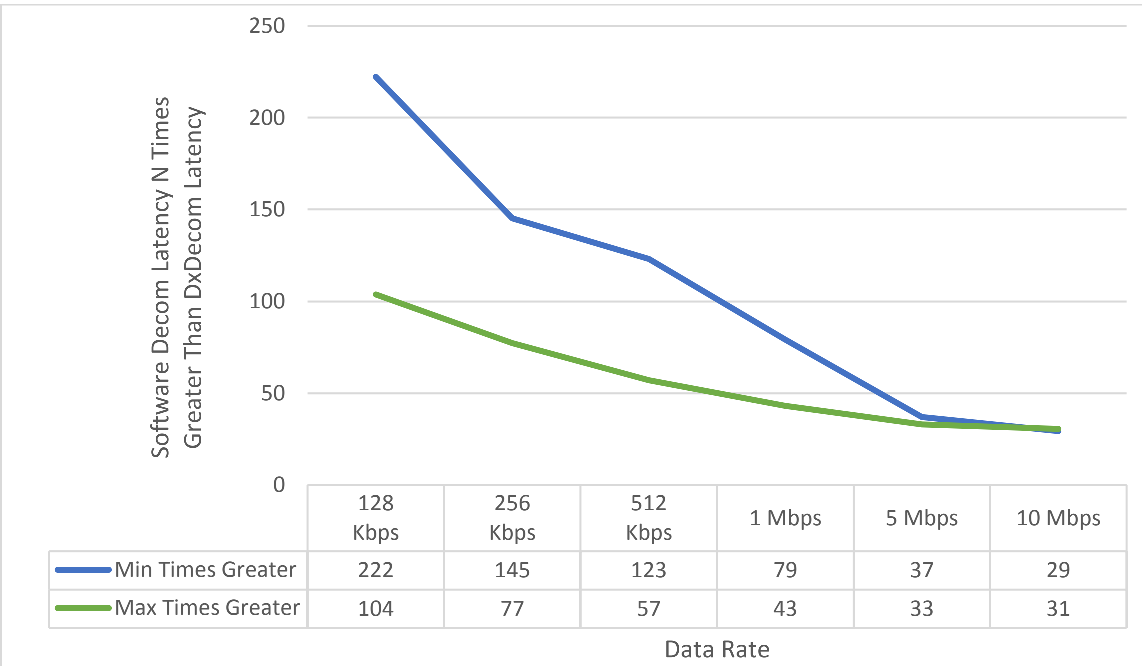
Table 7-1 Test Results (MCS with Software Decom Measured Latency)

	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
SW Decom Min	10.0	6.1	3.2	1.9	1.0	1.0
SW Decom Max	22.0	12.9	8.1	5.7	4.0	3.7
DxDecom Min	0.045	0.042	0.026	0.024	0.027	0.034
DxDecom Max	0.212	0.167	0.142	0.132	0.121	0.121

7.3. Observations

The test results show there is significant latency introduced by the Software Decom for low bit rates and a measurable amount of latency for high bit rates. Table 7-2 shows how many times greater the latency is between the Software Decom results and the DxDecom results.

Table 7-2 Software Decom Latency to DxDecom Latency Comparison



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
Min Times Greater	222	145	123	79	37	29
Max Times Greater	104	77	57	43	33	31

8. MCS WITH IOPLEX CAPTURE AND SOFTWARE DECOM

This section documents test results for telemetry data latency through the MCS telemetry processing system using a Software Decom along with the existing MCS ION bus. PCM data will be captured using an IOPlex.

8.1. Test Scenarios

A single Raw data scenario tests the latency of the data path from the PCM simulator through the IOPlex and the Software Decom to an MCS node with no EU data processing as shown in Figure 8-1. All other latencies should have equivalent deltas to standard MCS processing.

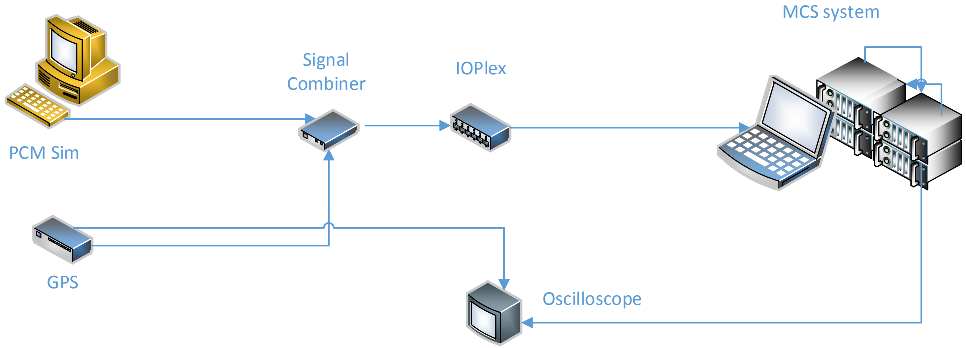
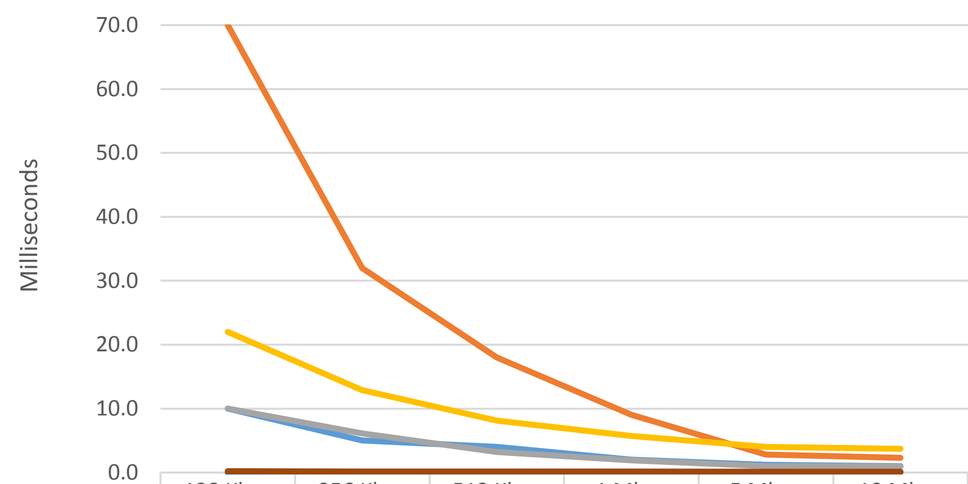


Figure 8-1 MCS with IOPlex Capture and Software Decom Data Flow

8.2. Test Results

The results of the raw data test at various data rates are shown in Table 8-1 below. The Software Decom / DxDecom and DxDecom-only based comparable latencies are also as referenced.

Table 8-1 Test Results (IOPlex Capture Measured Latency)



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
SD/IOPlex Min	10.0	5.0	4.0	2.0	1.2	1.0
SD/IOPlex Max	70.0	32.0	18.0	9.0	2.8	2.3
SD/DxDecom Min	10.0	6.1	3.2	1.9	1.0	1.0
SD/DxDecom Max	22.0	12.9	8.1	5.7	4.0	3.7
DxDecom Min	0.045	0.042	0.026	0.024	0.027	0.034
DxDecom Max	0.212	0.167	0.142	0.132	0.121	0.121

Data Rate

8.3. Observations

The test results show that there is significant latency introduced by the IOPlex/Software Decom for low bit rates and a measurable amount of latency for high bit rates. Table 8-2 shows how many times greater the latency is between the Software Decom results and the DxDecom results.

Table 8-2 Software Decom / IOPlex Latency to Software Decom / DxDecom Latency Comparison

9.   MCS WITH GSSRS IRIG 106 CHAPTER 10 CAPTURE AND SOFTWARE DECOM

This section documents test results for telemetry data latency through the MCS telemetry processing system using a Software Decom along with the existing MCS ION bus. PCM data will be captured using HEIM GSSrs Chapter 10 recorder.

9.1. Test Scenarios

Only raw data tests were used to measure the latency of the data path from the PCM simulator through the GSSrs and the Software Decom to an MCS node with no EU data processing as shown in Figure 9-1 below. All other latencies should have equivalent deltas to standard MCS processing.

Four scenarios were tested with the GSSrs. Two of the scenarios utilized the Windows Operating System on the GSSrs to broadcast the Chapter 10 data with different settings for buffer sizes. Wireshark was used to test the first of these two scenarios to measure packet burst delay. The second, third, and fourth scenarios were tested using the oscilloscope. The third and fourth scenarios utilized direct broadcast from the DATaRec 4 Link Module LMF1G that is internal to the recorder with different chapter 10 packet close-out time settings.

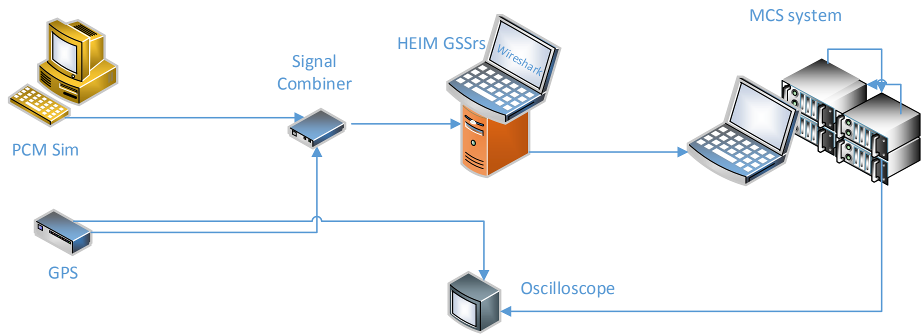


Figure 9-1 MCS With GSSrs Capture and Software Decom Data Flow

9.2. Test Results

When this test first began, the results displayed on the oscilloscope were so erratic that it was decided to not use the scope for the first test. Analysis of the collected measurements indicated that the GSSrs was buffering the data for a very long time and sending it out to the network in short bursts. These bursts and delays were measured using Wireshark on the GSSrs. Approximately 5 seconds worth of data was captured and the timestamps in Wireshark were used to determine the burst lengths and gaps. The maximum observed time delta value was recorded. The results of the Wireshark test at the various data rates are shown in Table 9-1 below.

Table 9-1 Test Results (Network Bursts)

Scenario	Data Rate	Delay Between Bursts	Burst Length
WIN 512K	128Kbps	970 ms	2 ms
WIN 512K	256Kbps	990 ms	2 ms
WIN 512K	512Kbps	960 ms	2 ms
WIN 512K	1Mbps	1100 ms	3 ms
WIN 512K	5Mbps	800 ms	10 ms
WIN 512K	10Mbps	300 ms	10 ms

After the first test, the setting for buffer length inside the GSSrs settings on Windows was altered and slightly better results were obtained. As these results were not as erratic, minimum and maximum latencies were measured. Burst delays were also using Wireshark on the GSSrs. The results are shown in Table 9-2 below.

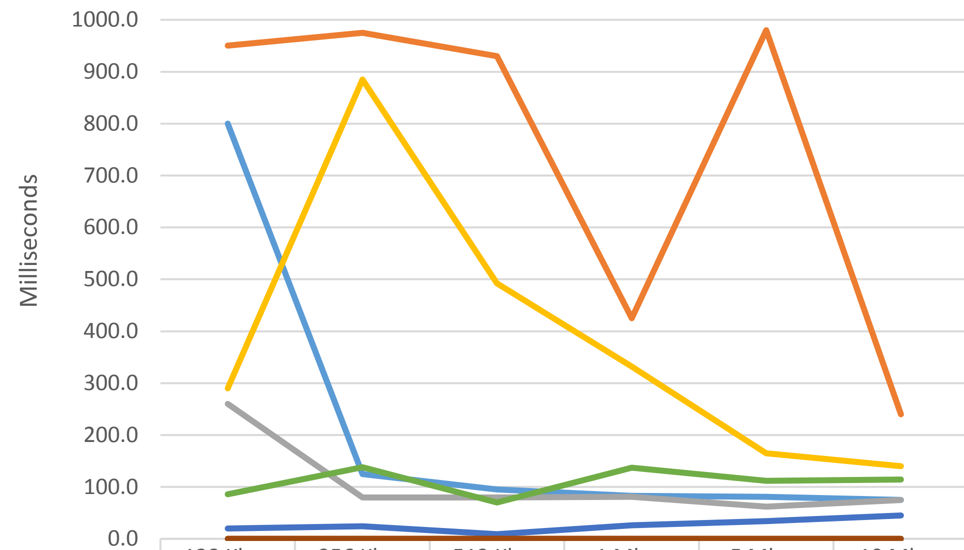
Table 9-2 Test Results (Auto Sized Buffers)

Scenario	Data Rate	Measured Min Latency	Measured Max Latency	Delay Between Bursts
WIN AUTO	128Kbps	800 ms	950 ms	1000 ms
WIN AUTO	256Kbps	125 ms	975 ms	800 ms
WIN AUTO	512Kbps	95 ms	930 ms	500 ms
WIN AUTO	1Mbps	83 ms	425 ms	300 ms
WIN AUTO	5Mbps	81 ms	980 ms	100 ms
WIN AUTO	10Mbps	75 ms	240 ms	100 ms

After these results were obtained, the LMF1G module inside the GSSrs was configured to directly broadcast the Chapter 10 packets to the network rather than going through the Windows host computer. Slightly better results were observed.

A visual anomaly was detected where multiple result pulses were observed on the scope for a single GPS strobe. No definitive explanation for this exists. One possibility is that the pulse somehow got split across packets that one packet was before a burst delay and one was after a burst delay. Another possibility is that the latency for one sample was greater than one second. No actual measurements of this anomaly were done. The results of the LMF1G test are shown in Table 9-3 below. After these results were obtained, the LMF1G module inside the GSSrs was configured to close Chapter 10 packets after 10 milliseconds (the maximum setting). The results are shown in Table 9-3 below.

Table 9-3 Test Results (WIN AUTO, LMF1G, and LMG1G-10ms results)



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
Win Auto Min	800.0	125.0	95.0	83.0	81.0	75.0
Win Auto Max	950.0	975.0	930.0	425.0	980.0	240.0
LMF1G Min	260.0	80.0	80.0	81.0	62.0	75.0
LMF1G Max	290.0	885.0	492.0	332.0	165.0	140.0
LMF1G-10ms Min	20.0	24.0	9.0	26.0	34.0	45.0
LMF1G-10ms Max	86.0	138.0	70.0	137.0	112.0	114.0
DxDecom Max	0.2	0.2	0.1	0.1	0.1	0.1

Data Rate

9.3. Observations

The test results show that there is significant latency introduced by using the GSSrs to packetize telemetry for the Software Decom for all bit rates. The Jitter is approximately 4 to 5 times the minimum latency measured for all bit rates.

10. MCS WITH IOPLEX CAPTURE AND SOFTWARE DECOM AND WITHOUT ION BUS

This section documents test results for telemetry data latency through the MCS telemetry processing system. This test is similar to the MCS IOPlex with Software Decom test above, however, there is no ION bus or DxDecom and the MCS software is run on a single computer.

All applications in this test are driven by the data, not by any rate that was dictated by the ION bus. Anytime data as written by one application, it immediately wakes up all other applications to process that data.

10.1. Test Scenarios

Three scenarios were tested: Raw data, EU data and APS data.

The Raw data scenario tests the latency of the data path from the PCM simulator through the Software Decom to an MCS node with no EU data processing.

The EU data scenario tests the latency of the data path from the PCM simulator through the Software Decom, through the MCS Data Processing Module (DPM) and then to an MCS node.

The APS data scenario tests the latency of the data path from the PCM simulator through the Software Decom, through the MCS Data Processing Module (DPM), through an APS module, and then to an MCS node.

The data flow was as shown in Figure 10-1 below.

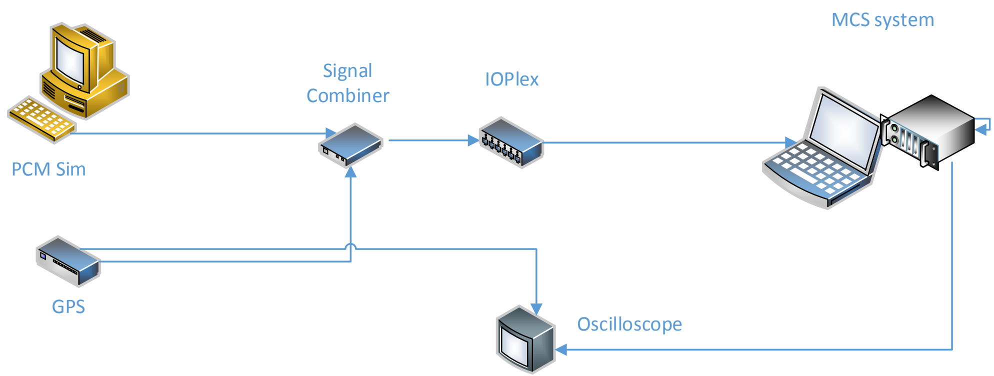
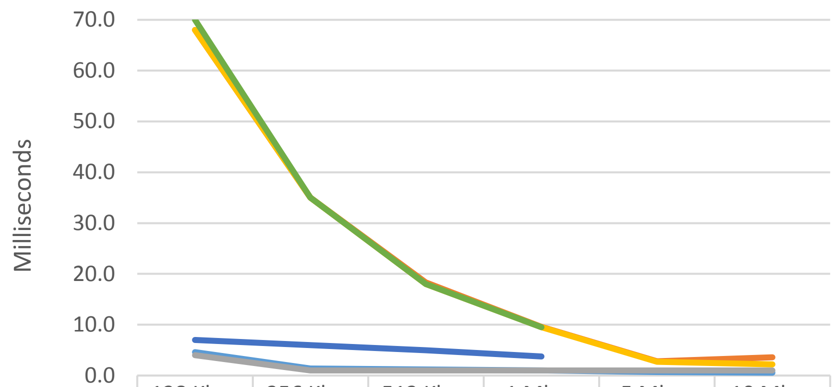


Figure 10-1 All Software MCS with IOPlex Capture and Software Decom Data Flow

10.2. Test Results

The results of all three scenarios at the various data rates are shown in Table 10-1 below.

Table 10-1 Test Results (All Software MCS Measured Latency)



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
SD/IOPlex-Single MCS RAW Min	4.6	1.4	1.2	1.0	0.7	0.6
SD/IOPlex-Single MCS RAW Max	68.0	35.0	18.3	9.6	2.8	3.6
SD/IOPlex-Single MCS EU Min	4.0	1.0	1.0	1.0	1.0	1.0
SD/IOPlex-Single MCS EU Max	68.0	35.0	18.0	9.5	2.7	2.2
SD/IOPlex-Single MCS APS Min	7.0	6.0	5.0	3.8		
SD/IOPlex-Single MCS APS Max	70.0	35.0	18.0	9.5		

Data Rate

10.3. Observations

The maximum latencies observed are consistent across all three types of measurements. The missing APS Min / Max results are due to the current software architecture's inability to keep up with the sample rate of the APS measurements generated at those bit rates.

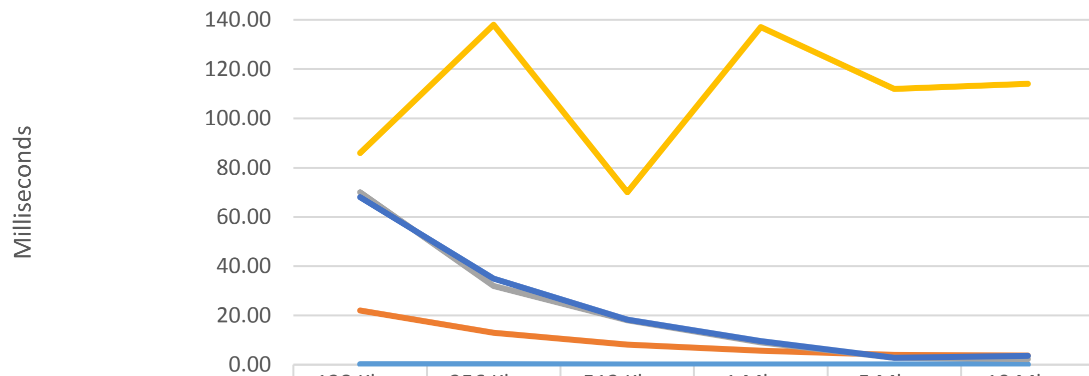
11. MCS COMPARISON

This section will compare the various individual MCS test results on a single chart.

11.1. Test Results

The results of all MCS raw data maximum latency tests are shown on Table 11-1 below.

Table 11-1 MCS Latency Comparison by Scenario with GSSrs

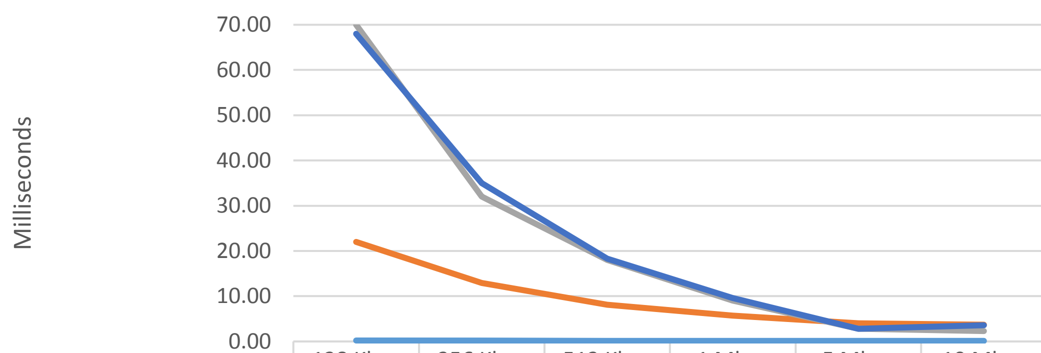


	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
DxD/ION MCS	0.21	0.17	0.14	0.13	0.12	0.12
Dxd/ION MCS DxDIn	22.0	12.9	8.1	5.7	4.0	3.7
DxD/ION MCS IOPlex	70.0	32.0	18.0	9.0	2.8	2.3
DxD/ION MCS CH10	86.0	138.0	70.0	137.0	112.0	114.0
Soft MCS IOPlex	68.0	35.0	18.3	9.6	2.8	3.6

Data Rate

The data from the Chapter 10 recorder clearly skews the results. To better see the differences in the other MCS results, Table 11-2 is shown below, which is the same as Table 11-1 above without the Chapter 10 results.

Table 11-2 MCS Latency Comparison by Scenario without GSSrs



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
DxD/ION MCS	0.21	0.17	0.14	0.13	0.12	0.12
Dxd/ION MCS DxDIn	22.0	12.9	8.1	5.7	4.0	3.7
DxD/ION MCS IOPlex	70.0	32.0	18.0	9.0	2.8	2.3
Soft MCS IOPlex	68.0	35.0	18.3	9.6	2.8	3.6

Data Rate

11.2. Observations

The data clearly shows the impact of the bit rate on the Software Decom latency. This is due to the duration of a PCM frame; the slower the data, the greater the latency.

12. DATA ACQUISITION AND TRANSMISSION SYSTEM

This section documents test results for telemetry data latency using the Edwards Data Acquisition and Transmission System (DATS).

12.1. Test Scenarios

Two primary DATS-based scenarios were tested: one loop and two loops through the DATS to RMCC as described in Table 12-1 below and shown in Figure 12-1 below.

Table 12-1 DATS Test Scenarios

Step	Scenario 1: Single-Loop DATS-RMCC	Scenario 2: Dual-Loop DATS-RMCC
1	PCM Simulator	PCM Simulator
2	Signal Combiner	Signal Combiner
3	Bore site Modulator	Bore site Modulator
4	Bore site	Bore site
5	Antenna	Antenna
6	Receiver	Receiver
7	IOPlex1	IOPlex1
8	IOPlex2	IOPlex2
9	IOPlex3	IOPlex1
10	MCS	IOPlex3
11		IOPlex4
12		IOPlex3
13		MCS

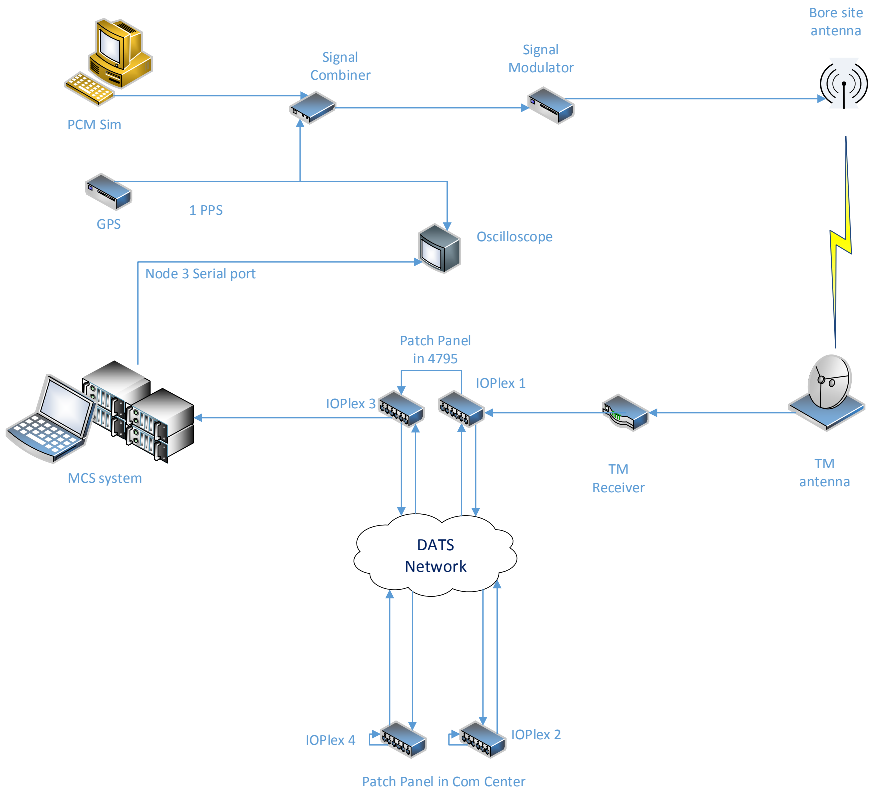


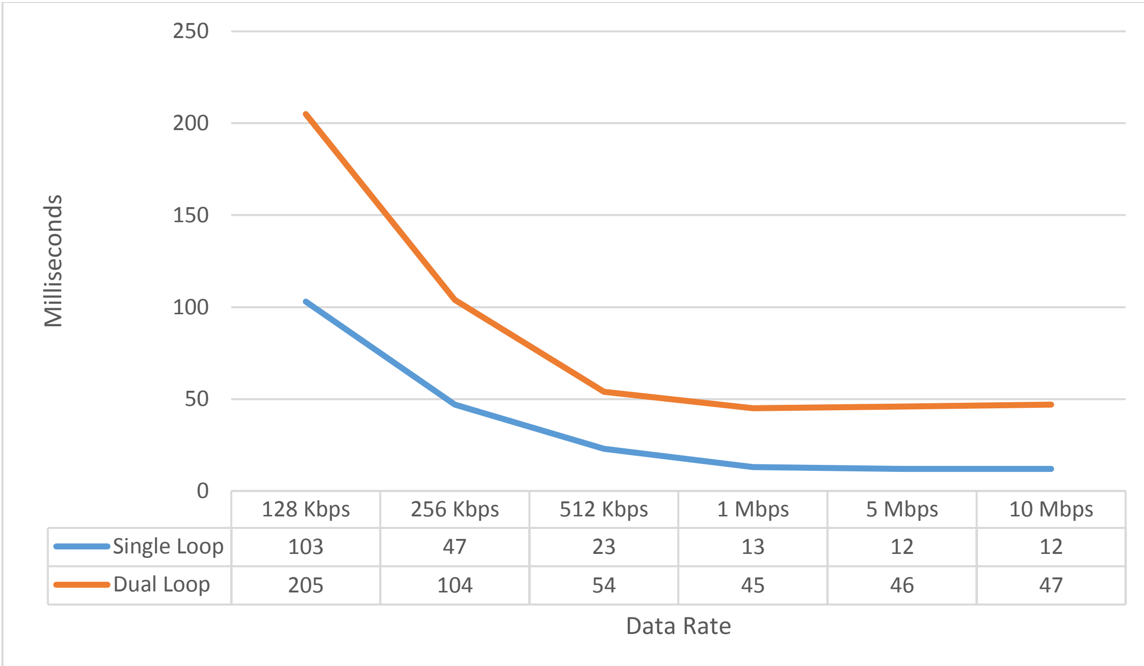
Figure 12-1 DATS Data Flow

To ensure the system itself had no effect on the measured latency, a single latency test similar to scenario 1 was performed without sending the data through DATS to RMCC. The measured latency of this test was approximately 200 µs, which is less than the estimated error of +/- 1 millisecond (ms) for this test.

12.2. Test Results

The results of the two test scenarios are listed and graphed in Table 12-2 below.

Table 12-2 Test Results (DATS Measured Latency Single and Dual Loop)

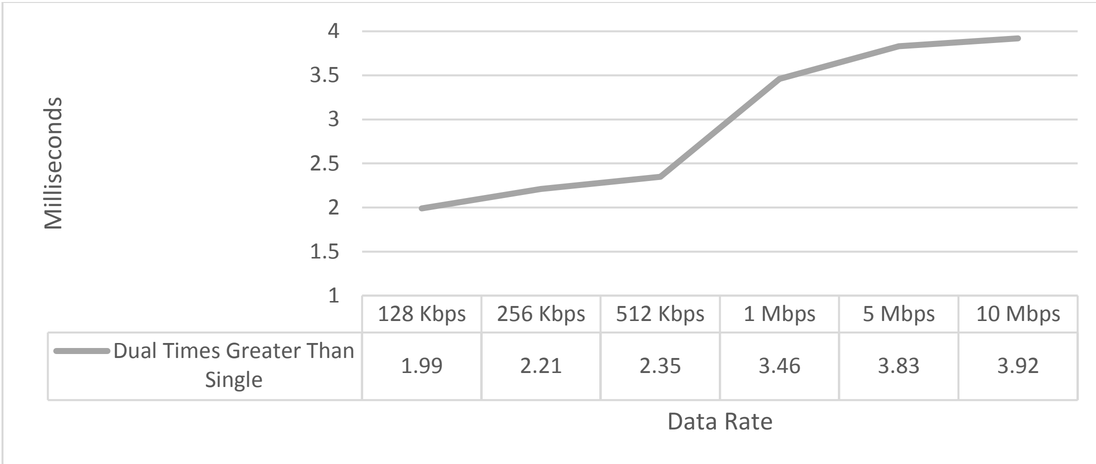


12.3. Observations

- For data rates below 1 Mbps:
    - Data latency decreases as the data rate increases
    - Data latency for two loops appears to be two times (2x) the data latency of a single loop
- For data rates above 1 Mbps:
    - Data latency remains approximately constant
    - Data latency for two loops appears to be four times (4x) the data latency of a single loop

Table 12-3 shows how many time greater the latency is between the Single Loop and Dual Loop configurations.

Table 12-3 DATS Single and Dual Loop Latency Comparison



13. IADS SYSTEM LATENCY

This section documents test results for telemetry data latency through the Interactive Analysis and Display System (IADS). An IADS control was created to write a byte to the serial port whenever its bound parameter was non-zero.

13.1. Test Scenarios

Two EU test scenarios were performed using the IADS. The value of two Caching Data Server (CDS) startup file settings were set to different values for each of the two test scenarios. The two settings are named STAGE_SIZE_IN_MILLISECONDS and DATA_SOURCE_BUFFER_SIZE_IN_MILLISECONDS.

The first test scenario used the default settings used by the CDS. The default value for each setting is 20 milliseconds. This setting uses a packet rate of 50 packets/second from the MCS. The second test scenario set these two settings to one to make latency as small as possible. This setting uses a packet rate of 1000 packets/second from the MCS. No attempt to determine what other ramifications this had on the IADS system was done.

The data flow was as shown in Figure 13-1 below.

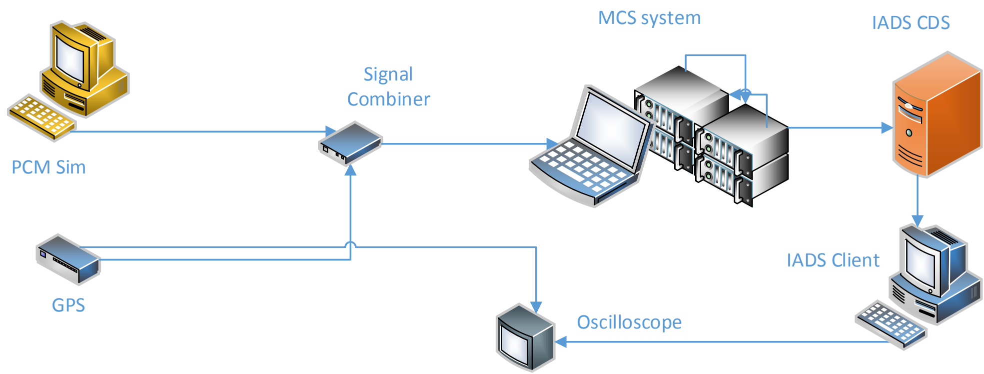
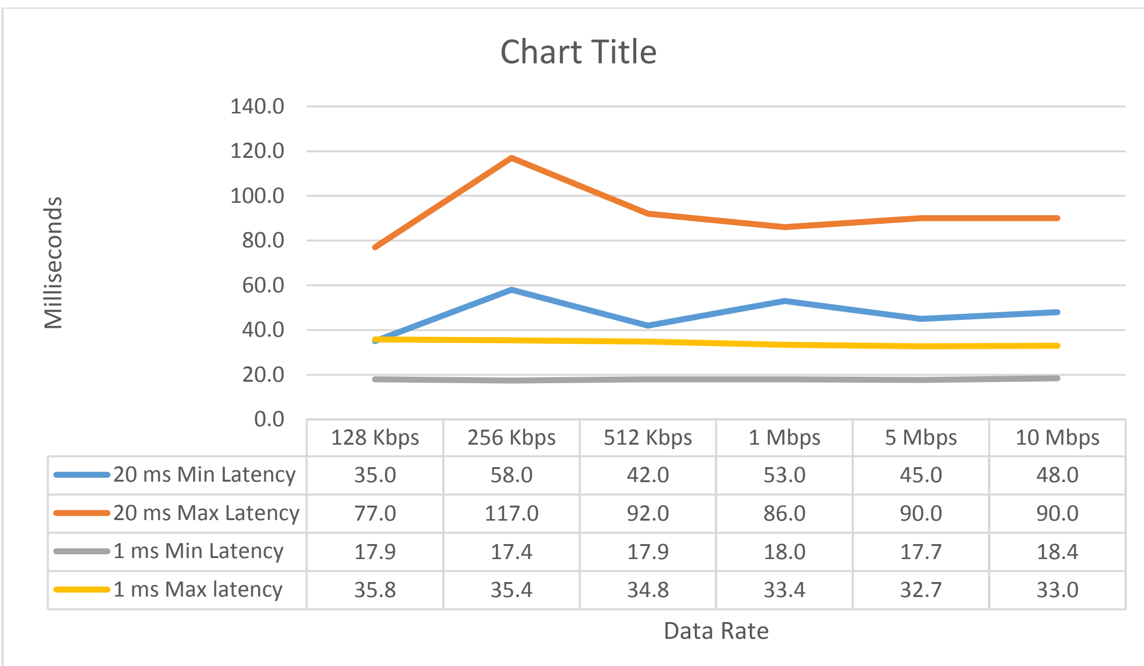


Figure 13-1 IADS Data Flow

13.2. Test Results

The results of the data test at the various data rates are shown in Table 13-1 below.

Table 13-1 Test Results (Measured Latency)



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
20 ms Min Latency	35.0	58.0	42.0	53.0	45.0	48.0
20 ms Max Latency	77.0	117.0	92.0	86.0	90.0	90.0
1 ms Min Latency	17.9	17.4	17.9	18.0	17.7	18.4
1 ms Max latency	35.8	35.4	34.8	33.4	32.7	33.0

13.3. Observations

The APS test scenario measurements were aperiodic and the high rate of data caused the IADS system problems. The update rate was very low and time tagging of the data was erratic due to the sample rate of the measurements being far greater than the rate of time.

Since Raw data was only a few microseconds of latency difference than EU data on the MCS system, it was decided this was an insignificant difference compared to the expected latencies of the IADS system.

For the 20 ms setting, sample rates and word latencies seem to have no discernable effect on the measured IADS latency. All measured numbers seem pure random, however, minimum measured latencies are all less than all maximum measured latencies.

For the 1 ms setting, the observed minimum and maximum latencies seem consistent regardless of sample rate. When these measurements were taken on the oscilloscope, an interesting phenomenon was observed. The latency would hover around 100 ms for a while (bouncing between 95 and 105), then hover around 80 ms (bouncing between 85 ms and 75 ms), then hover around 60 ms, 40 ms, 20 ms, and then increase back to 100 ms.

14. RF CODING LATENCY

New Radio Frequency (RF) coding schemes such as Space Time Coding (STC) and Low-Density Parity Check (LDPC) cause new latencies in the RF arena. This section will attempt to characterize these latencies for the purpose of complete system latency.

14.1. Test Scenarios

These latencies were measured by an external group and the answers reported in terms of number of bits at a particular bit rate of latency. These are shown in Table 14-1 below.

Table 14-1 RF Latencies

Bit Rate	STC	LDPC 4096 2/3	STC + LDPC 4096 2/3
1Mbps	736 bits	8306 bits	8332 bits
5Mbps	765 bits	8389 bits	8351 bits
10Mbps	769 bits	8464 bits	8336 bits

14.2. Test Results

To obtain delays in microseconds is easy math. The results in microseconds are in Table 14-2 below.

Table 14-2 RF Latencies in Microseconds

Bit Rate	STC	LDPC 4096 2/3	STC + LDPC 4096 2/3
1Mbps	736 µs	8306 µs	8332 µs
5Mbps	153 µs	1677.8 µs	1670.2 µs
10Mbps	76.9 µs	846.4 µs	833.6 µs

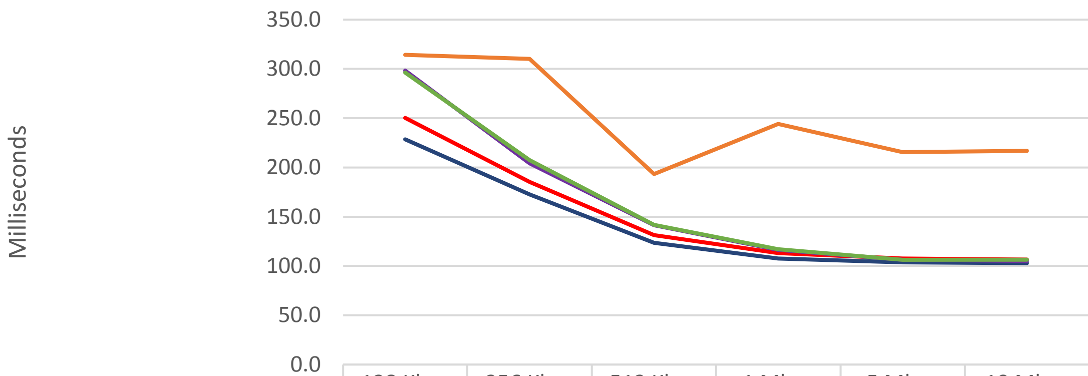
14.3. Observations

STC causes a much smaller latency to be added. LDPC is much higher as it requires buffering of blocks of data in the receiver to evaluate the forward error correction before passing the data downstream.

15. TOTAL SYSTEM LATENCY

Table 15-1 as follows shows the total max system latency of data including RF, MCS, IADS and DATS latencies.

Table 15-1 Test Results (Total System Measured Latency)



	128 Kbps	256 Kbps	512 Kbps	1 Mbps	5 Mbps	10 Mbps
DxD/ION MCS Total	228.5	172.5	123.5	107.5	103.8	103.0
Dxd/ION MCS DxDIn Total	250.3	185.2	131.4	113.0	107.7	106.5
DxD/ION MCS IOPlex Total	298.3	204.3	141.3	116.3	106.5	105.1
DxD/ION MCS CH10 Total	314.3	310.3	193.3	244.3	215.7	216.8
Soft MCS IOPlex Total	296.3	207.3	141.6	116.9	106.5	106.4

Data Rate

16. REVISION HISTORY

Revision	Date	Description	Name
Initial	July 13, 2017	Telemetry System Latency Report	J. Morgan

17. METADATA

Contract Data Requirement List (CDRL) Sequence Number	Not Applicable (N/A)
Exact Document Title	Telemetry System Latency Report
Formal Document Number	JT3-AFC-SRPT-17172-0005
Document Type	Report
Document State	Official
Document Category	B
Keyword	None
Document Handling Statement	None
Approval Authority Name	Chris Grenz
Document Effectivity Date	July 13, 2017
Document Author Name	Jon Morgan
Document Owner Name	Delane Allen
Retention Period	Contract Termination – Range Management System (RMS) Delivery
Review Schedule	As Required
Next Review Date	As Required
Revision	Initial Release
Revision Effectivity Date	N/A